Modeling Supercritical CO_2 Injection in Brine-Bearing Formations

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RESEARCH OBJECTIVES

Geologic sequestration of CO_2 in brine-bearing formations has been proposed as a means of reducing the atmospheric load of greenhouse gases. Numerous brine-bearing formations have been identified as having potential for geologic sequestration of CO_2. One promising setting is the fluvial/deltaic Frio formation in the upper Texas gulf coast, which is the site of an upcoming pilot test of CO_2 sequestration. The objective of this research is to investigate the physical processes controlling the behavior and ultimate fate of CO_2 in the subsurface, to help design the pilot test and to gain a broader understanding of the issues accompanying CO_2 sequestration in brine-bearing formations.

APPROACH

To evaluate CO_2 sequestration scenarios, we use the numerical simulator TOUGH2, which considers all flow and transport processes relevant for a two-phase (liquid-gas), three-component (CO_2, water, dissolved NaCl) system. In the subsurface, supercritical CO_2 forms an immiscible gas-like phase and partially dissolves in the brine.

A three-dimensional numerical model is developed of the pilot test site, a 450 m × 450 m dipping fault block containing several wells that penetrate the 12 m thick brine-saturated sand near the top of the Frio that is our sequestration target. Under the planned sequestration conditions (P = 150 bars, T = 66°C), supercritical CO_2 is strongly buoyant compared to the native brine.

ACCOMPLISHMENTS

We have simulated a number of alternative scenarios for the pilot test, varying three types of model parameters:

- Operational parameters such as injection and monitoring well locations and injection schedule
- Geological features such as the continuity of shale layers, the connectivity of sand channels, and the permeability of faults
- Multiphase flow properties such as relative permeability curves

Simulations show that relative permeability functions have a strong effect on CO_2 plume development. Because most of our knowledge and experience concerning relative permeability for the Frio comes from petroleum reservoirs, in which liquid phases displace a pre-existing gas phase, how to choose appropriate relative permeability functions for supercritical CO_2 injection into a brine-saturated formation is still an open question. Snapshots of the simulated supercritical CO_2 plume (Figure 1) show the impact of relative permeability. For relative permeability functions with large residual gas saturation S_{gr}, the plume is compact and does not move much under buoyancy forces, because much of the gas is immobile. In contrast, for relative permeability functions with small S_{gr}, the plume is more diffuse. It moves and spreads significantly over time, allowing a much larger fraction of the CO_2 to dissolve in the brine.

SIGNIFICANCE OF FINDINGS

The ability to numerically simulate the complex multiphase flow processes involved in CO_2 injection is critical to developing a good experimental design for the pilot test, just as it will ultimately be for designing successful sequestration operations.

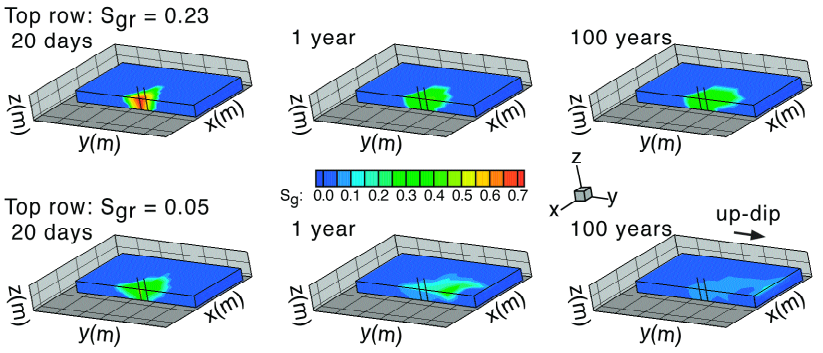

Figure 1. Modeled gas saturation distribution after 20 days of injection of supercritical CO_2 into a brine-saturated formation, for two different values of residual gas saturation S_{gr}. The injection and monitoring wells are shown as black lines.

The residual gas saturation used in the relative permeability functions is a key factor controlling the development of the CO_2 plume. Future laboratory and field work will be directed toward determining appropriate values of S_{gr} for CO_2 injection into brine-bearing formations.

RELATED PUBLICATIONS

Doughty, C., and K. Pruess, Modeling supercritical CO_2 injection in heterogeneous porous media. Presented at TOUGH Symposium 2003, Berkeley Lab., Berkeley, California, May 12–14, 2003.

Related web site: http://www-esd.lbl.gov/GEOSEQ/index.html

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